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Overview of Hawaiian Dry Forest Propagation Techniques

Compiled by The Nature Conservancy of Hawaii

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Statewide, the rare Hawaiian dry forest ecosystem has been reduced to less than 10% of its original extent, and restoration may be the only way to save it. Inspired by a desire to restore the Kanepu'u Dry Forest on Lana'i, The Nature Conservancy designed the "Hawaiian Dry Forest Propagation Survey" to compile and synthesize propagation information on Hawaiian dry forest species. In addition to the species native to Kanepu'u Dry Forest, the survey was broadened to include related dry forest tree species in an attempt to make the results applicable to the broader restoration effort in Hawai'i.

The Hawaiian Dry Forest Propagation Survey included the following materials: an overview survey of propagation techniques, a summary of previously published propagation techniques for several individual species, and a "propagation tips" form requesting detailed information for each of the 35 listed species. We were unable to include every knowledgeable person due to time and other constraints, and extend our apologies to those whom we failed to contact. Of 35 people who were sent the survey in 1996-7, 13 responded (Appendix 1). The wealth of information they provided is summarized in this report. Special thanks for their substantial contributions are due to Bruce Koebele, Kerin Lilleeng-Rosenberger, Jeanine Lum, Richard Nakagawa, and Anna Palomino.

This report compiles knowledge and experience to date with growing species included in the Hawaiian Dry Forest Propagation

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Survey. The survey respondents suggested many other species (herbs, shrubs, subalpine types, etc.) that they had some experience with and that they felt should be included in the list. The information they provided on most of these additional species was insufficient to merit inclusion here; only Caesalpinia kavaiensis has been added to the original list. Ideally, this overview should some day be expanded to include all dry forest species; it currently focuses on the most common elements, especially those found on Lana'i. Perhaps one of our readers will be inspired to pick up where we left off and expand the document to include the further wealth of information that is available.

General Propagation Techniques for Dry Forest Species

Seed propagation is unpredictable: there are numerous variables to consider, and some cannot be controlled. In addition, many seedlings grow very slowly requiring a great deal of patience and persistence on the part of the grower. What works for one person may not work for another, due in part to variations among the individual propagators' "styles," as well as to their nursery situations and capabilities. There is also enormous variation among seeds, available sunlight and moisture, soil type and fertility, etc. Recognizing this, the survey did not strive for absolutely consistent, quantifiable data; rather, it was designed to elicit the full range of individual's experiences.

Fortunately, there are some general propagation concepts and techniques which, if understood, can be applied in individual situations. The tips below are compiled from the comments of several growers regarding their general experiences with growing dry forest species. Further information can be found in the references at the end of this compilation.

Seeds (source, quality, fertility): A high rate of success depends largely on the use of fresh, viable seeds. For seed sources, select only plants that are growing well in the wild at the time. Choosing plants by flower quality or new traits alone can narrow the gene pool for a species. Timing of seed collection and sowing is also important, as is the detection and advance removal of nonviable seeds. There is much variability among the seeds themselves, even from the same source.

It is often helpful to open some seeds to assess the thickness of the seed coat or to determine their viability by verifying the presence of an embryo. (For example, some fruits, such as *Myoporum* and *Styphelia*, are mistaken for seeds. They are actually multi-seeded drupes, and may contain no seeds at all.) Flowering strategies (i.e., whether a plant is monoecious, dioecious. etc.) may also make a difference as to whether a particular plant's flowers are pollinated efficiently or not.

Seed Preparation: If time and resources permit, germination time can often be decreased with soaking and scarification (although "no pretreatment" may work fine, too). Soak for about 24 hours—less for small, thin seeds, more for large, thick seeds—in water that is 115-120° or 160-180°F (opinions vary as to the optimal temperature, but boiling is usually too hot). Variability in seed coat thickness affects heat tolerance—the same temperature can work fine on one seed and kill another of the same species. Scarification can be done by any number of techniques depending on seed size and the propagators ingenuity. When clipping and sanding, be careful with how much and where the seed is scarified. and don't scarify on or near the hilum.

The section below on Individual Species Propagation Tips describes a couple of fairly standard preparation methods for most species. The following is an alternative to these standard treatments that has worked very well for one grower:

> Sterilize the seeds in a 10-15% Clorox solution for 15-30 minutes, then rinse thoroughly with water (rinsing is optional). Plant seeds in a small tray (a bento or tofu container with holes drilled in the bottom works well) filled with horticultural-grade vermiculite. Cover seeds with a thin layer of "green moss" available at many garden shops (the green moss is believed to inhibit fungal growth). (A pinch of sulfite can also be added to further inhibit fungus.) Water thoroughly and cover with a clear container. Rewater periodically to keep the vermiculite and moss moist. When the seeds germinate, allow them to develop 1-2 sets of true leaves. then transfer to individual pots (2" square by 4" deep) containing a potting medium of 2 parts fine cinder, 1 part vermiculite, and 1 part new potting soil (commercial). Because the seedlings are in pure vermiculite, transferring them seems to cause little root damage. Place a small amount of

slow-release fertilizer on top of the medium in each pot.

Medium: The medium varies with the species, and there are many possibilities. Two standard media that work for most species are suggested in the Individual Species Propagation Tips below. Other growers suggest: 1) 1 part peat, 2 parts perlite, covered with screened cinder or fine grit depending on the size of the seed; 2) 1 bag perlite, 1/2 cinder, 1 bag peat moss, 1/4 bag sand: 3) 1 part perlite. 1 part Sunshine #5. Other comments: 1) vermiculite is the best sterile medium to use, but only for a short period of time as it absorbs moisture and gets very soggy; 2) generally, cinder should be avoided in germinating mixes, as root injuries are heavy during transplanting: 3) cinder, if available (perlite can be substituted) can be used for up to 50-90% of the medium: also, cinder can be strained to produce different "types" of media—sometimes the size of the seed dictates the "grade," as smaller seeds can be buried too deeply by large-sized particles.

Water and drainage: Good drainage and an appropriate watering regime are critical for germination of most dry forest species. The watering regime depends on the medium, the nurser location and situation (e.g., shaded greenhouse, full sun, wind, etc.), and the type and size of the container. It is probably better to have too much drainage and risk underwatering than the reverse. Uhiuhi, sandalwood, and lama can never have enough drainage. Drenching flats several times per week rather than daily seems to work best for dryland species, although opinions differ.

Sowing and transplanting: One grower suggests that, if time and resources permit, transplanting time can be saved by sowing seeds with faster germination times (1-2 months) and higher germination rates (50% and up) in individual containers. Others suggest that, because most seeds germinate over a long period of time, it is preferable to sow in flats and then transplant as soon as possible into containers (use a medium of 1:2:1 peat, perlite, and 1/8" screened black cinder), and continue to drench several times per week, making sure that adequate drying occurs between waterings. Once seedlings are established and putting on good growth, move them out to full sun, which seems to help build up stem thickness and lignify tissue. Adequate spacing between plants helps to minimize plant-to-plant contact and encourage air circulation, thus reducing disease problems.

Fertilization: Fertilize regularly when the plant is young, in a pot, and growing up, then moderately once it is planted in the ground. Add slow-release fertilizer at a low rate to all growing mixes and supplement with liquid fertilizer. Use a foliar fertilizer with equal formulation (15-16- 17) plus micronutrients every other week at 100 ppm nitrogen. To supplement species with slower root development (*Caesalpinia*, *Colubrina*, *Santalum*), use a foliar fertilizer higher in phosphorus.

Storage: There are two standard techniques suggested throughout the Individual Species Propagation Tips.

Pests: Fungi and slugs are the biggest threats to seedlings.

Outplanting: If planting is being done to prevent erosion, choose plants that will establish themselves and grow quickly. Of the species on the list, the fastest growing are *Abutilon*, *Dodonaea*, *Myoporum*, *Sida*, and *Waltheria* (it might even be worthwhile to simply broadcast some of these seeds in the wild). The other species need a lot of "hand-holding" to get started.

Outplanting can be complex and controversial. Techniques will vary and must be adapted to the natural conditions—habitat, terrain, slope, soil conditions, etc. For the initial outplanting, a reliable water source is mandatory. In general, the best time to outplant is at the beginning of the winter rainy season—it can save resources, water, time, etc. Summer is generally not recommended as many of these species just do not do much at this time, even if water is supplied. A berm and mulch (if possible) can also help to conserve water. Soil augmentation. even with poorly drained and/or clay-like soil, does not seem to benefit outplantings: native soil works best.

For at least one grower, the most serious outplanting problem is damage from the Chinese rose beetle (*Adoretus sinicus*). There is no effective deterrent or control.

Individual Species Propagation Tips

In the survey, usually only three or four people—sometimes just one or two—commented on their experiences with an individual species, or on a particular aspect of growing that species. In the summaries below, we have tried to capture the

diversity of growers' experiences, as well as consistency among them when it exists. When growers suggested alternative techniques, their descriptions have been separated by the word *"or"*. While these sometimes conflicting descriptions may be confusing, they also provide evidence that there is no absolute recipe for plant propagation. We hope that this compilation will provide some new tips and comparative experiences for those who are currently growing a species, as well as encouragement and techniques for those who want to start growing new ones. The tips for each species fall into five categories: **Propagation**, **Germination**, **Storage**, **Pests**, and **Notes**, as described below.

Propagation: includes seed preparation instructions, medium type and proportions, preferred containers for germinating and transplanting seeds, watering instructions and other suggestions for optimal germination, and suggestions for transplanting and fertilization.

Germination: time from planting to germination, and germination success rates.

Storage: techniques for cleaning and preparing seeds to induce dormancy for storage, as well as preferred containers and conditions.

Pests: those that affect seeds and seedlings.

Notes: other information that does not fall into the above categories.

Sometimes the instructions for propagation or storage call for standard seed-cleaning procedures. Kerin Lilleeng-Rosenberger suggests the following techniques:

Dry Seed Cleaning Procedure:
- Leave seed material out or in a paper bag and air-dry at room temperature.
- Set a strainer (choose hole size according to seed size) over a bowl.
- Empty seed material into the strainer; carefully rub it so that the seeds fall through the container and the debris is left.
- Discard the debris.

Fleshy/Pulpy Seed Cleaning Procedure:
- Ripen seeds in a plastic bag. (Seeds are easier to clean when the pulp is softened.)
- Once ripened, remove the flesh to prevent spoilage. One way that works best with large seeds is to use a colander or strainer placed under running water. (A concentrated stream can really help.) Rub seeds to dislodge the pulp. Another way is to put the seeds in a large bowl of water and massage the seeds by hand to separate them from the pulp. The heavy (good) seeds will sink to the bottom; the lighter pulp and empty seeds will float to the top and can be poured off. (Note: this is true for the species specified. However, a floating seed does not always mean it is not viable; some seeds disperse by floating.)
- Wash the seeds thoroughly.
- Dry them on a paper towel.

Abutilon eremitopetalum / A. menziesii (Hidden-petaled 'ilima & Ko'oloa'ula)

MALVACEAE

Propagation: Collect seed capsules after ripening, usually in a dry state, and spread in shade for further drying. Remove seed from capsules, soak 1-24 hours in tap or hot water until seeds sink, and discard floaters.

3:1 perlite #2, Sunshine Mix #4 or 1:1:1 peat, perlite, soil
Plant 1/8" deep in shallow flats.
Water every other day, keeping medium moist until germination. *or* Reduce water after emergence to prevent damping-off.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth.
Transplant into individual containers (3.5-4" square).

Germination: soaked seeds—2-4 weeks; unsoaked seeds—3-6 months; success high (95%). Use liquid fertilizer during this period.

Storage: Pry open capsules to release seeds (or shake or beat fruit in bag or other container to dislodge seeds) Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%). *or* Dry in shade, then put in sealed glass container and refrigerate.

Pests: Chinese rose beetle.

Notes: Grows easily from seeds or cuttings. Beware of hybrids if growing both *Abutilon* species.

Alphitonia ponderosa (Kauila)
RHAMNACEAE

Propagation: Black seeds have two coats. Use hammer to remove first coat, then clippers to remove second coat. Soak in tap water for 7 days, change every other day. Discard floaters. *or* Scarify and soak 24 hours; discard floaters. *or* Collect seeds from opened capsules: do not soak.

3:1 perlite #2. Sunshine Mix #4
Plant seeds 1" apart in shallow flats.
Water every other day, keeping medium moist until germination; avoid damping off
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: soaked seeds—if scarified, 6 weeks to 3 months (10-50% success), otherwise 3-6 months (10% success): unsoaked seeds—from opened capsules, 3 weeks to 8 months (7-30% success). otherwise, 9-12 months.

Storage: Can store with seed coats on or removed. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Notes: Very difficult to cut through hard fruit. Can also try a knife or cutting pliers.

Antidesma platyphyllum (Hame)
EUPHORBIACEAE

No information provided.

Bobea sandwicensis ('Ahakea)
RUBIACEAE

Propagation: Remove pulp (two seeds per berry). If pulp is difficult to remove, soak one day in tap water. Best to use fresh seeds; just clean and sow.

3:1 perlite #2, Sunshine Mix #4 or 4:1 cinder, soil
Plant 1/8" deep in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area or in greenhouse (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 4 weeks to 3 months; success poor (10%).

Storage: Remove pulp and air-dry seeds. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Bonamia menziesii
CONVOLVULACEAE

Propagation: Grown easily from seed. Remove pulp and plant fresh seeds. or Scarify and soak 2 hours in 120° water. *or* Soak 24 hours in cold water.

3:1 perlite #2, Sunshine Mix #4 or 1:1:1 peat, perlite, soil or 4:1 cinder. soil
Plant 1/4" deep in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered. shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth. Can also plant in full sun.
Transplant into individual containers (3.5-4" square) after true leaves are fully formed.
Use liquid fertilizer at seedling stage.
Acclimate gradually to full sun; use slow-release fertilizer (14-14-14).

Germination: 2-4 weeks, success high.

Storage: Seeds are best started fresh. If necessary to store, remove pulp by hand or in strainer. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%). *or* Dry fruits in shade; large seeds can then be removed easily from dried capsules. Put in sealed glass container and refrigerate.

Notes: Can also be grown from cuttings with difficult . Plant in 100% cinder, keep in greenhouse and do not mist.

Caesalpinia kavaiensis (Uhiuhi)
FABACEAE

Propagation: Remove seeds from capsules. Scarify with clippers, file, or sandpaper on seed edge (away from tip where hilum and micropyle are located).

3:1 perlite #2, Sunshine Mix #4
Plant individual seeds 1/8" deep in 3" pots (does not transplant well).

Water every other day, keeping well-drained and on the dry side (susceptible to root rot).
Supplement with high-phosphorus foliar fertilizer to assist slow root development, and do not over-fertilize with nitrogen, even though the foliage may look pretty.

Germination: 5-7 days if seeds are healthy: success rate 100% with healthy seeds. Seeds with holes bored by beetles ma y rot and not germinate.

Storage: Remove from capsules. Air-dry at room temperature and store in paper envelope. Seeds can be desiccated and kept in refrigerator or freezer.

Pests: Beetles that bore holes in seeds; mealy bugs in root area (especially when root development is poor); ants.

Notes: May grow slowly after initial burst; occasionally tips die.

Charpentiera obovata (Papala)
AMARANTHACEAE

Propagation: Follow Dry Seed Cleaning Procedure (dry seeds in paper bag). *or* Store without pretreatment.

3:1 perlite #2, Sunshine Mix #4 *or* 1:1:1 peat. perlite. soil
Sprinkle small seeds on medium in shallow flats.
Mist with fine spray, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth.
Transplant into individual containers (3.5-4" square).
Use liquid fertilizer at seedling stage.
Acclimate gradually to full sun; use slow-release fertilizer (14-14-14).

Germination: with pretreatment about 2 weeks to 1 month; without pretreatment, 8-16 weeks. High success.

Storage: Follow Dry Seed Cleaning Procedure (dry seeds in shade). Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%). *or* Dry panicles in sun or shade; small seeds can then be removed easily with fingers. Put in sealed glass container and refrigerate.

Cocculus trilobus (Huehue)
MENISPERMACEAE

Propagation: Remove seeds from capsules. Soak 1 hour in tap water; discard floaters.

3:1 perlite #2, Sunshine Mix #4
Plant seeds 1/8" deep in shallow flats.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 1-3 months or more; poor success.

Storage: Remove seeds from capsules; keep dry. Dry at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Colubrina oppositifolia (Kauila)
RHAMNACEAE

Propagation: Remove seeds from capsules. Soak 3 days in tap water or scarify with clippers or file. *or* Soak in 170° water for 24 hours; discard floaters.

3:1 perlite #2, Sunshine Mix #4 or 4:1 cinder. soil
Plant in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: soaked seeds—2 weeks to 2 months (scarified seeds germinate 5 days sooner), 65% success (40% if soaked in 170° water); unsoaked seeds—3 weeks to 3 months. 40% success.

Storage: Remove seeds from capsules: keep dry. Do not soak or scarify, just put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool dry place (relative humidity 25%).

Notes: Has slow root development so use a high-phosphorus foliar fertilizer.

Diospyros sandwicensis (Lama)
EBENACEAE

Propagation: Grown easily from seed. Follow Fleshy/Pulpy Seed Cleaning Procedure to remove fleshy orange pulp from light brown seeds. Seeds

can be started fresh with no pretreatment. *or* can be soaked overnight in warm or tap water.

3:1 perlite #2, Sunshine Mix #4, or 1:1:1 peat, perlite, soil
Plant 1/8" deep in shallow flats.
Water every other day, keeping medium moist until germination; good drainage is key.
Keep flats in covered. shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth.
Transplant into individual containers (3.5-4" square) after first true leaves are fully formed.
Use liquid fertilizer at seedling stage.
Acclimate gradually to full sun; use slow-release fertilizer (14-14-14).

Germination: 25 days to 2 months; very good (50-90%) success, depending on seed viability at time of collection (or 8-16 weeks if soaked overnight; 50% success). (Scarification and soaking in hot water can decrease germination time from 3 months to 1 month; 60% success)

Storage: Poor germination with dried seed; best to use fresh material. If necessary to store, remove pulp (soaking overnight helps to soften) and air-dry seeds. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Notes: Very slow growing—2-3" in 6 months.

Dodonaea viscosa ('A'ali'i)
SAPINDACEAE

Propagation: Remove seeds manually from paper capsules or follow Dry Seed Cleaning Procedure. Soaking can increase and speed germination, but may not be necessary with fresh seeds. Soak seeds for 4-24 hours in tap or hot water; discard floaters.

3:1 perlite #2, Sunshine Mix #4
Plant seeds 1/8" deep in shallow flats, or put 2 seeds each in quart-sized gro-bags.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth. Full sun may be preferred as too much water is not tolerated.
Transplant into individual containers (3.5-4" square) when seedlings have 2 sets of leaves. then to ground when 6-24" tall.

Germination: 1 week to 6 months; moderate to good success, 50% and up, depending on seed health at time of collection.

Storage: Remove seeds from paper capsules: air-dry at room temperature and keep dry. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: No pests of consequence; occasionally thrips in nursery.

Notes: Best grown from seeds, but can also use cuttings or air layers.

Erythrina sandwicensis (Wiliwili)
FABACEAE

Propagation: Grown easily and rapidly from seeds. Remove large red to orange seeds from pods and soak in 120° water for 1 hour or more (only until they swell; seeds will rot if they take in too much water). Careful scarification with clippers or by sanding speeds up germination.

3:1 perlite #2, Sunshine Mix #4 or 4:1 cinder, soil
Plant seeds just below surface, several per 6" pot, or one per 3" pot. The latter method results in less root damage when transplanting.
Needs maximum sunshine and well-drained soils. Keep on the dry side; moisture encourages fungi and mites, and seeds rot easily.
Slow release fertilizer (14-14-14) at half dosage is recommended.

Germination: 4-5 days with scarification, longer if not. Success high (90-100%).

Storage: Remove seeds from pods and keep dry. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%) or in refrigerator.

Pests: Chinese rose beetles and spider mites can be problems. Young plants are sometimes attacked by a leaf-eating caterpillar. Overwatering, too much shade, or the rainy; season can bring powdery mildew to leaves. Mature plants have few pests.

Notes: Can also be grown from cuttings (2-6") and from air layers.

Gardenia brighamii (Nanu/Na'u)
RUBIACEAE

Propagation: Follow Fleshy/Pulpy Seed Cleaning Procedure to remove seeds from fruit. Soak one hour in tap water, then sow. Best if sowed fresh.

3:1 perlite #2, Sunshine Mix #4
Plant 1/4" apart in shallow flats.
Water every other day, keeping medium moist until germination; needs good drainage.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 4-5 weeks, up to one year (longer if not soaked). Success very good if sowed fresh; if desiccated, fewer germinate.

Storage: Remove pulp, air-dry at room temperature (not in sun). Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Notes: Can also graft or air layer.

Kokia drynarioides (Koki'o)
MALVACEAE

Propagation: Grown easily from seed. Remove brown hairy seeds from capsules and manually remove some of the hair to reveal a smooth seed coat. Nick seed coat with clipper and sow. Can also soak 4 hours or overnight in 120° water.

3:1 perlite #2, Sunshine Mix #4 or 1:1:1 peat, perlite, soil
Plant seeds 1/8" deep in shallow flats or individual 3" containers to reduce transplant root disturbance.
Water every other day, keeping medium moist until germination. Reduce water after emergence to prevent damping-off. Needs good drainage.
Keep flats in covered. shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth.
If planted in flats. transplant to individual containers as soon as first true leaves are fully formed.
Use liquid fertilizer at seedling stage.

Germination: 10 days if scarified; 100% success if seeds are good (or 1 week to several months, with 50-65% success, if scarified and soaked).

Storage: Seeds store well. Remove seeds from capsules; air-dry at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool dry place (relative humidity 25%). *or* Dry in shade; put in sealed glass container and refrigerate.

Pests: Aphids love this plants—need to control ants. Chinese rose beetles also seem to cause some damage.

Notes: Can also graft or air layer.

Metrosideros polymorpha ('Ohi'a)
MYRTACEAE

Propagation: Grown easily from seeds. Best to plant fresh seeds as soon as possible. Collect seed capsules when brown; place in paper bag or envelope, let dry. Dust-like seeds will fall out of open seed capsules. No further treatment is necessary.

3:1 perlite #2. Sunshine Mix #4 or black cinder or 1:1 potting mix. fine grade cinder or sterile potting soil
Sprinkle seeds onto firm, moist medium in shallow flats.
Water gently every 1-2 days (mist is best), keeping medium moist and well drained.
Keep flats in covered. shaded area or in greenhouse (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth or in sun.
Transplant into individual containers (3.5-4" square) when seedlings have two sets of leaves. Use well-drained medium of 3 :1:1 potting mix, perlite, cinder.
Use slow-release fertilizer (14-14-14).

Germination: 1 week to 3 months: success rates are variable and moderate (very high with fresh seeds). Germination can be low or none after storage.

Storage: Seeds do not store well; they lose viability. If necessary to store. remove from capsules and air-dry at room temperature . Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%). Will also germinate at reduced rates after 3~ years of refrigerated storage.

Pests: Rose beetles, nematodes, and root-rotting fungi. Ants (carrying scale, aphids, etc.) can

weaken plant. Control thrips with water pressure or mild insecticidal soap.

Notes: Can also grow from cuttings or air layers. Cuttings: Select 1/4" diameter wood, 4-6" long. Tip and stem cuttings with healthy leaves work best. Cut leaves in half and remove leaves from lower inch of the cutting. Dip cutting into strong rooting hormone solution for 10 seconds. Good rooting medium is 1:1 perlite, peat moss or pure vermiculite or pure perlite. Air layers: Follow standard practices, using a strong rooting hormone.

Myoporum sandwicense (Naio)
MYOPORACEAE

Propagation: Use fresh seeds. Fruit is a drupe and has unusual multiple seeds within. Collect only large, ripe, white and juicy fruits; many smaller ones have no seeds. Remove pulp; follow Fleshy/Pulpy Seed Cleaning Procedure. Soak cleaned seeds in tap water or hand-hot water 12-48 hours or longer. Change water daily. Sanding may speed up germination but is troublesome.

3:1 perlite #2, Sunshine Mix #4
Plant in shallow flats.
Water every other day, keeping medium moist until germination, and well-aerated.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: Varies widely, from less than one month to 18 months. Best results with fresh seeds. Success is variable, from low to very good (10-70%) depending on health of seed at time of harvest. Once germinated, growth can be very fast, almost weedy.

Storage: Best to use fresh fruit. If storage is necessary, remove pulp and air-dry at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: Few problems, occasionally spider mites and powdery mildew; may be susceptible to nematodes.

Notes: Can also be grown from cuttings (success depends on age of plant). Air layering produces large plants fast.

Myrsine lanaiensis (Kolea)
MYRSINACEAE

Propagation: Soak 24 hours and remove floaters.

Germination: Six to twelve months; very low rates due to low seed viability .

Notes: Difficult to grow; most success from sprouting root runners.

Nesoluma polynesicum (Keahi)
SAPOTACEAE

Propagation: Remove pulp; follow Fleshy/Pulpy Seed Cleaning Procedure. Soak seeds 48 hours in tap water; discard floaters.

3:1 perlite #2, Sunshine Mix #4 or 1:1:1 peat, perlite, soil
Plant l/8" deep in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth.
Transplant into individual containers (3.5-4" square).
Use liquid fertilizer at seedling stage.
Acclimate gradually to full sun; use slow-release fertilizer (14-14-14).

Germination: 8 weeks to 6 months, very good success with fresh, healthy seeds.

Storage: Remove pulp, air-dry at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool. dry place (relative humidity 25%). *or* Dry in sun (no cleaning is necessary). Put in sealed glass container and refrigerate.

Nestegis sandwicensis (Olopua)
OLEACEAE

Propagation: Remove pulp; follow Fleshy/Pulpy Seed Cleaning Procedure. Soak in tap water 24 hours; discard floaters. *or* Crack and remove seed coat. Soak 2 hours at room temperature, then put in Petri dish on filter paper. Radical forms in 2-3 weeks, with germination 1-2 weeks later.

3:1 perlite #2. Sunshine Mix #4
Plant seeds 1/8" deep in shallow flats.
Water every other day, keeping medium moist until germination.

Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 2-3 weeks to 6-9 months; good success if seeds are viable (some problems with rotting).

Storage: Remove pulp. Put in paper envelope or bag then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: Protect seeds from rats.

Nothocestrum breviflorum ('Aiea)
SOLANACEAE

Propagation: Follow Dry Seed Cleaning Procedure. No further treatment is necessary.

3:1 perlite #2, Sunshine Mix #4
Plant in shallow flats; sprinkle 1/16" of medium on top of small seeds.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 1-5 months; transplant at 4 months; good success with fresh, healthy seeds.

Storage: Follow Dry Seed Cleaning Procedure. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: Cucumber beetles can be a problem with young seedlings.

Nothocestrum latifolium ('Aiea)
SOLANACEAE

Propagation: Follow Dry Seed Cleaning Procedure. No further treatment is necessary.

3:1 perlite #2, Sunshine Mix #4 or 4:1 cinder, soil
Plant in shallow flats: sprinkle small seeds on medium and press down.
Water every other day, keeping medium moist until germination.
Keep flats under 50% shade cloth.
Transplant into individual containers (3.5-4" square) when 1" high.

Germination: 8-16 weeks; success moderate; slow-growing.

Storage: Follow Dry Seed Cleaning Procedure. Dry in shade; put in sealed glass container and refrigerate.

Pisonia sandwicensis
(Papala kepau/aula)
NYCTAGINACEAE

Propagation: Grown easily from seed with no pretreatment necessary .

1:1:1 peat, perlite, soil
Separate seeds and plant 1/4" deep in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats under 50% shade cloth.
Transplant into individual containers (3.5-4" square).
Use liquid fertilizer at seedling stage.
Use slow-release fertilizer (14-14-14) after 6" of growth.

Germination: 6-12 weeks; moderate success.

Pleomele sp.
AGAVACEAE

Propagation: Remove pulp; follow Fleshy/Pulpy Seed Cleaning Procedure. Treat with a fungicide to prevent rotting. Air-dry seeds on paper towel before sowing.

3:1 perlite #2, Sunshine Mix #4
Plant in shallow flats.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).
Transplant as soon as possible.

Germination: 5 weeks to 6 months; low rate (5-10%). Seeds tend to rot easily if medium is kept too wet or if fungicide is not used.

Storage: Does not store well; best to start fresh. If necessary to store, air-dry on paper towel at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Notes: Can also be grown from cuttings.

Pouteria sandwicensis ('Ala'a)
SAPOTACEAE

Propagation: Grown easily from seed. Remove pulp, soak seeds in fungicide (follow label

directions) for 10 minutes, then sow. Scarification or overnight soaking in hot water may help.

1:1:1 peat, perlite, soil or black cinder
Plant seeds 1/2" deep in shallow flats or 4-6" individual containers or tree tubes (for tap roots).
Water every other day keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings) or under 50% shade cloth.
Transplant into individual containers (3.5-4" square) after first true leaves are fully developed.
Use liquid fertilizer at seedling stage.
Acclimate gradually to full sun; use slow-release fertilizer (14-14-14).

Germination: 6 weeks to 8 months. with low to high success, depending on freshness and viability of seeds and potential for rotting; slow growing.

Storage: Start fresh; does not store well (loses viability). *or* Seeds can be removed easily from ripe, soft fruits. Dry in shade; put in sealed glass container and refrigerate.

Psydrax odoratum (Alahe'e) (*Canthium odoratum*)
RUBIACEAE

Propagation: Grown easily from seeds. Soak 24-48 hours in tap water; change daily.

3:1 perlite #2, Sunshine Mix #4, or 1:1 perlite, peat moss
Plant in shallow flats.
Water every other day, keeping medium moist until germination. Keep well-drained.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).
Transplant into individual containers (3.5-4" square) when first true leaves emerge. Use 2:1:1 peat moss, cinder, perlite.
Fertilize young plants regularly with organic and slow-release fertilizers incorporated into potting medium, and with foliar fertilizer.

Germination: can be slow, from 1 to 6 months. Success rates are very good if seeds are good, but most are damaged and must be discarded. Seedlings grow slowly at first, then increase in speed once in the ground.

Storage: Remove pulp and air-dry on paper towel at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: Most seeds are attacked by a parasite and will not germinate. Spraying seeds during development on parent tree will prevent this problem. Overfertilized or overshaded seedlings and young plants may be attacked by sucking insects such as aphids and scales. Treat with insecticidal soap or standard insecticides and ant bait.

Rauvolfia sandwicensis (Hao)
APOCYNACEAE

Propagation: Remove pulp from seeds, then soak seeds 5 hours in tap water. Seeds should sink to bottom: air-dry on paper towel.

3:1 perlite #2, Sunshine Mix #4
Plant in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 1 to 6 months; good success if seeds are good.

Storage: Best to start fresh. If necessary to store, remove pulp, air-dry on paper towel at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: Ants can sometimes bring in scale.

Reynoldsia sandwicensis ('Ohe)
ARALIACEAE

Propagation: Grown easily from seeds. Follow Fleshy/Pulpy Seed Cleaning Procedure, then soak 1-6 hours in tap water. Seeds should sink to bottom after 1 hour; discard floaters.

3:1 perlite #2, Sunshine Mix #4, or 1:1:1 peat, perlite. soil
Plant in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered. shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth.

Transplant into individual containers (3.5-4" square) after first true leaves emerge.
Use liquid fertilizer at seedling stage.
Acclimate gradually to full sun; use slow-release fertilizer (14-14-14).

Germination: 1-6 months if seeds are fresh and not old, good to very good success if viable seeds are used.

Storage: Best to start fresh: loses viability with storage. If necessary to store, follow Fleshy/Pulpy Seed Cleaning Procedure. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%). *or* Dry in shade; put in sealed glass container and refrigerate.

Santalum freycinetianum ('Iliahi)
SANTALACEAE

Propagation: Remove pulp; follow Fleshy/Pulpy Seed Cleaning Procedure. Soak 24 hours in tap

water; seeds should sink to bottom. Soak 5 minutes in fungicide and air-dry at room temperature

before sowing. *or* Soak several weeks, changing water and removing pulp from seeds several

times each day.

3:1 perlite #2. Sunshine Mix #4
Plant in shallow flats.
Water every other day keeping medium moist until germination, but well-drained.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).
Transplant into individual containers (3.5-4" square) after 2-3 pairs of true leaves have formed. Somewhat difficult to transplant: if seed does not fall off readily from cotyledon. do not bother to transplant. Protect from rodents and birds by covering flats or tables with wire cages.

Germination: 1 month to 1 year; fair to low success (10-50%). Seeds are very susceptible to rot, but fungicide helps. The fresher the seed, the better.

Storage: Remove pulp, air-dry on paper towels at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Notes: May or may not need host plant during seedling stage; can have good results without one. Pruning the host plant can be a lot work. May be more important for outplanting.

Sapindus oahuensis (Lonomea/Aulu)
SAPINDACEAE

Propagation: Remove pulp and scarify seeds (with file or lightly on grinder) or soak (1 hour in hand-hot water or 24 hours in tap water). *or* Remove all seed coats and propagate with embryo.

3:1 perlite #2. Sunshine Mix #4
Plant in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 1-6 months (may start to rot after 2 months); very good success if seeds are

healthy. Embryo propagation: 1 week; very good success.

Storage: Remove pulp and air-dry on paper towel at room temperature. Put in paper envelope or bag. then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: Twig/stem borer (affects stems up to 1 mm in diameter); Chinese rose beetle: small gray weevil.

Notes: Fast growing if all the pests are controlled.

Senna gaudichaudii (Kolomona)
FABACEAE

Propagation: Best grown from seed. Pretreatment is usually preferred; nicking or scarificatio n reduces germination time, and seeds should be soaked in 120° water until they take in water (up to 24 hours), then cooled 24 hours. Discard floaters.

3:1 perlite #2. Sunshine Mix #4 or 1:1 peat. perlite
Plant in shallow flats; good drainage is critical.
Water every other day, keeping medium moist until germination.
Keep flats in covered. shaded area (to control moisture and to keep rain from harming seeds and seedlings). *or* Keep in full sun and water daily.

Germination: Varies. With soaking and/or scarification, 5 days to 2 months. Moderate success if seeds have not been eaten by insects.

Storage: Remove seeds from pods; if wet, air-dry at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: Few are reported, although seeds are often attacked.

Notes: This is not a very hearty plant; it does not do well in "red dirt" (Pearl City type, well-drained).

Sida fallax ('Ilima)
MALVACEAE

Propagation: Grown easily from seeds with no special care needed. Remove seeds from capsules and soak 1-24 hours in hand-hot or tap water; discard floaters and dry seeds on paper towel.

3:1 perlite #2, Sunshine Mix #4
Plant in shallow flats.
Water every other day, keeping medium moist until germination. Beach ecotypes need less water than upland ecotypes.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings). May be able to start in full sun. Fungi attack leaves if conditions are too moist.

Germination: 10 days to 3 months; erratic. Success rates also vary from none to very good. Seedlings grow quickly.

Storage: Remove seeds from capsules; can shake or beat in bag to dislodge most seeds. Air-dry at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Pests: Upland ecotypes may be susceptible to nematodes; beach ecotypes appear to be resistant. Ant-associated pests (scales and mealybugs) can be a problem.

Notes: Can also grow from cuttings (80-90% success rate).

Styphelia tameiameiae (Pukiawe)
EPACRIDACEAE

Propagation: Seeds (.5 mm) in multi-seeded drupe. Best results from gently cracking drupe with hammer and removing seeds. then soaking 20 minutes in vinegar followed by 2 hours in 120° water. *or* Remove red-orange pulp; follow Fleshy/Pulpy Seed Cleaning Procedure. Soak seeds in hand-hot water for a few hours or tap water for 24-48 hours. Helps to soak hard seed coat 5 minutes in 5% acetic acid. then rinse thoroughly with fresh water through a strainer.

3:1 perlite #2, Sunshine Mix #4 or 1:1:1 peat, perlite, soil or black cinder
Plant 1/8-1/2" deep in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings), or under 50% shade cloth.
Transplant into individual containers (3.5-4" square) after first true leaves are fully developed.
Use liquid fertilizer at seedling stage.
Acclimate gradually to full sun; use slow-release fertilizer (14-14-14).

Germination: 1-6 months, with 50% success rate if crack drupe to remove seeds and soak in water and vinegar; otherwise 16 weeks to 9 months with poor to moderate success rate.

Storage: Best to start fresh seed. If necessary to store, follow Fleshy/Pulpy Seed Cleaning Procedure and air-dry on paper towel at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%). *or* Dry in shade; put in sealed glass container and refrigerate.

Notes: A difficult species to grow. Digging up seedlings from the wild works best, but is not good for the wild! Germination, if it occurs, is very slow, as is subsequent growth. Seed source may be important because of flowering strategy. Many flowers may not be pollinated, but drupes may still occur with varying amounts of seed production. Might be faster to air-layer 12" plants; these may take 4-6 months to form roots. Nene also propagate pukiawe.

Waltheria indica ('Uhaloa)
STERCULIACEAE

Propagation: Follow Dry Seed Cleaning Procedure. No further pretreatment is necessary.

3 :1 perlite #2, Sunshine Mix #4
Plant 1/8" deep in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 1-3 months, very good success.

Storage: Follow Dry Seed Cleaning Procedure and air-dry if wet on paper towel. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool. Dry place (relative humidity 25%).

Xylosma Hawaiiense (Maua)
FLACOURTIACEAE

Propagation: Follow Fleshy/Pulpy Seed Cleaning Procedure. No further pretreatment is necessary (can soak 1/2 hour in tap water).

Sphagnum moss or 2:1 perlite, potting mix
Plant 1/8" deep in shallow flats.
Water every other day, keeping medium moist until germination.
Keep flats in covered, shaded area (to control moisture and to keep rain from harming seeds and seedlings).

Germination: 1-6 months; fair to good success.

Storage: For best germination, start with fresh seeds. If necessary to store, follow Fleshy /Pulpy Seed Cleaning Procedure. Air-dry on paper towel at room temperature. Put in paper envelope or bag, then in airtight container with silica gel or other desiccant. Keep in cool, dry place (relative humidity 25%).

Notes: Seeds are susceptible to rot.

Zanthoxylum dipetalum (Kawa'u)
RUTACEAE

Germination: 5 weeks to 6 months; success 20-50%.

Pests: Bird damage.

Notes: Difficult to outplant. Need to provide shade and protection from ants.

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Storing Seeds of Some Native Rain Forest Plants: Some Simple Methods

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Many plants produce seeds only infrequently or for only a short period during the year. This is a problem for growers since, without special storage measures, stored seeds often deteriorate rapidly. Here I describe some simple methods which can prolong the storage lives of seeds of many Hawaiian rainforest plants a year or more.

Not all seeds can be successfully stored. For those which can tolerate desiccation, the keys to extending their storage life are control of storage temperature and humidity.

Orthodox seeds typically dry naturally on the mother plant. They can be dried to low moisture contents without harm. Drying prolongs seed life, often considerably. Koa (*Acacia koa*) is a familiar local example.

Recalcitrant seeds typically fall from the mother plant when still moist. If dried below a critical moisture content, they die. They are usually short-lived and intolerant of low temperature. Many large tropical rain forest seeds such as coffee, mangoes and palms are recalcitrant.

A third category, intermediate seeds, has been proposed for seeds which can tolerate some desiccation but not freezing.

There is still little information about effective storage methods for tropical seeds other than crop plants. For Hawaiian plants in particular, there is almost no published information; see Yoshinaga et al. (1998). Recommendations in this article are based mainly on ongoing research conducted at Lyon Arboretum by the University of Hawai'i Center for Conservation Research and Training.

Two Simple Storage Methods

While there are many methods for storing seeds, not all of them are practical for small-scale growers. Here I present two methods which require little specialized equipment and have proven successful with many species of Hawaiian rain forest plants with small dry seeds:

Method I: Low Humidity Storage

In this method, seeds are kept at room temperature in sealed airtight containers with desiccated silica gel to maintain the air humidity inside the containers below 10% relative humidity.

After collecting the seeds, clean them and dry them thoroughly. If they are moist, spread them in a thin layer and dry them with a fan. Do not use heat; high temperature drying will substantially shorten the seeds' storage life. After they are dry, lower their moisture content down to storage level by placing them in an airtight container with desiccated silica gel. The seeds should be in a thin layer so that pockets of moisture do not develop in the mass of seeds. Monitor the air humidity within the container and change the silica gel as necessary until the relative humidity stays below 10%. An alternative to silica gel is vacuum drying.

Once the seed are desiccated, transfer them to permanent storage in a sealed airtight container with silica gel to keep the humidity low. Keep a humidity indicator in the container if you can, to monitor the humidity during storage.

Both silica gel and relative humidity indicator cards are available from photographic equipment suppliers. (Silica gel is sometimes available for

free from places which receive shipments of electronic equipment.) Humidity indicator cards are also available from Light Impressions, PO Box 940, Rochester, NY 14603-0940, tel. # 1 (800) 828-6216

After silica gel has absorbed moisture, it needs to be recharged. If no instructions accompany the gel, recharge it in an oven at 250°F for 12-16 hours. Small quantities can be recharged more easily and quickly in a microwave oven.

Method II: Refrigeration

In this method, seeds are kept in an open container inside an ordinary refrigerator at 39°F (4°C). The build-up of frost on the freezer coils will tend to dry the air. If possible, the refrigerator should be dedicated to seed storage, since frequently opening the door will raise the humidity inside. In Honolulu, if the refrigerator rarely opened, the inside relative humidity will stay near 10%. If the door is opened often, humidity may rise to 20-40%.

Clean and dry the seeds as described for Method I above. After they are dry, spread them in a thin layer inside the refrigerator to allow them to dry further. Once they have dried to the humidity inside, you can store them in open containers in the refrigerator. With either storage method, it is a good idea to germinate a batch of seeds shortly after collection to verify that the seeds are viable.

Note: After storage at low humidities, some seeds may suffer imbibition damage if wetted. To prevent this, allow the seeds to absorb moisture from the air by placing them in a very humid container for a day before sowing them. This does not appear to be a problem for most of the species listed below.

Other Storage Methods

Room Temperature and Humidity

At the Lyon Arboretum in Honolulu, the range of air temperature and relative humidity over the year at the seed storage location is from 13-29°C (55-84°F) and 58%-98% RH. Under these storage conditions, seeds of most native rain forest plants deteriorate rapidly; often the loss of viability is noticeable within a few weeks of collection. This method is not recommended for storage of most seeds, except for very short periods.

Refrigeration + Desiccation

Similar to Method II above, but the seeds are stored in the refrigerator inside sealed containers with silica gel to lower relative humidity below 10%. For the length of time we have tested this method (up to 1 year so far), we have found few species for which it works better than Method II. It may be superior for longer periods.

Frozen Storage

Seeds are stored in a freezer at -18°C (0°F). Seeds must be desiccated before freezing, otherwise internal ice crystals will form and damage the seeds. In principle, if seeds can tolerate desiccation and freezing, they should keep for longer under frozen storage than at warmer temperatures. We have just begun testing frozen storage of native Hawaiian plant seeds. A surprising proportion of the seeds tested so far can tolerate freezing, so the method shows promise.

Cryogenic Storage

For very long storage periods (i.e., many years), cryogenic storage in liquid nitrogen at -150 to -196°C (-238 to -320°F) is widely used. This requires specialized equipment and so is not practical for most horticulturists or land managers. However, it is a valuable method for maintaining germplasm collections. Research on cryogenic storage of seeds of native Hawaiian plants is under way at the U. S. Department of Agriculture's National Seed Storage Laboratory in Ft. Collins, Colorado.

Imbibed Storage

Seeds of some plants store best when kept moist (Vázquez-Yanes and Orozco-Segovia 1996). We have just begun research on imbibed storage of Hawaiian seeds at both room temperature and under refrigeration, storing seeds on agar or damp sphagnum moss to keep them moist. This method is promising for some recalcitrant seeds and small seeds which require strong light for germination.

Recommendations By Species

Below is an alphabetical list of species of native Hawaiian plants for which there is some data on seed longevity. Storage recommendations are tentative. With longer study, recommendations may change. The numbers in parenthesis give the length of storage studies so far.

Acacia koa

Though there have been no controlled storage studies of koa seeds, there is considerable anecdotal evidence that they keep well for years at room temperature and humidity. Low humidity or

refrigeration would probably extend storage life even further.

Antidesma platyphyllum (1 yr.)
Short storage life; satisfactory storage methods not yet developed. Under refrigeration + desiccation, a few seeds remain viable after six months. Currently testing refrigerated imbibed storage.

Bidens asymmetrica (6 mo.)
Noticeable deterioration after three months at room temperature and humidity. After six months, viability of seeds stored under low humidity or refrigeration is indistinguishable from fresh seeds. Seeds tolerate freezing.

Bidens sandvicensis (1 yr.)
Noticeable deterioration after three months at room temperature and humidity. Viability of seeds stored under low humidity or refrigeration is indistinguishable from fresh seeds after a year. Seeds tolerate freezing.

Boehmeria grandis (2 yrs.)
Noticeable deterioration after three months at room temperature and humidity. Low humidity storage is suitable for a year or less. Seeds stored under refrigeration retain good viability for at least two years. Seeds tolerate freezing.

Clermontia kakeana (2 yrs.)
Poor viability after three months at room temperature and humidity. A few seeds remain viable after two years under low humidity or refrigeration + desiccation. Refrigeration would probably be equally effective. Seeds tolerate freezing.

Cyanea angustifolia (2 yrs.)
Noticeable deterioration after one month at room temperature and humidity. A few seeds remain viable after two years under low humidity or refrigeration + desiccation but seedlings were weak. Refrigeration would probably be equally effective. Seeds tolerate freezing.

Diospyros sandwicensis (3 mos.)
Satisfactory methods not yet developed. Seeds deteriorate rapidly after ripening and mold readily in storage. Difficult to dry effectively. Research in progress with vacuum drying and imbibed refrigerated storage.

Hedyotis acuminata (1 yr.)
Very poor viability after six months at room temperature and humidity. Viability after one year under refrigeration + desiccation indistinguishable from fresh seeds. Refrigeration, not tested, probably would be similar. Some seeds remained viable under low humidity storage after one year.

Hedyotis terminalis (2 yrs.)
Viability still good after six months at room temperature and humidity. Some seeds still viable after two years under refrigeration and low humidity storage. Seeds tolerate freezing.

Heteropogon contortus (3+ yrs.)
There have been no controlled storage studies of *H. contortus* seeds in Hawaii. In Australia, seeds stored in an air-tight container at room temperature retained good viability for over 39 months (Tothill 1977). Hawaiian *H. contortus* has lower germination rates than Tothill measured, so its storage life may be shorter. In Hawaii, low humidity storage might be preferable.

Labordia tinifolia (2 yrs.)
Very poor viability after two months at room temperature and humidity. Some seeds still viable after two years under refrigeration.

Metrosideros polymorpha
There have been no controlled storage studies of *M. polymorpha* seeds. Anecdotal evidence indicates that seeds stored at room temperature and humidity decline rapidly after a few months (Burton 1982). Seeds tolerate freezing.

Osteomeles anthyllidifolia (1 yr.)
Very poor viability after a year storage at room temperature and humidity. Very good viability under refrigeration + desiccation. Refrigeration would probably work equally well. Seeds tolerate freezing.

Peperomia latifolia (6 mos.)
No seeds remain viable after six months storage at room temperature and humidity. Viability of seeds stored under refrigeration is indistinguishable from fresh seeds. Seeds tolerate freezing.

Peperomia leptostachya (6 mos.)
Satisfactory storage methods not yet developed. Seeds stored under either room

temperature and humidity or refrigeration + desiccation no longer viable after three months.

Peperomia sandwicensis (3 mos.)

After 3 months, viability at room temperature and humidity is declining, while viability under low humidity and refrigeration remains good. Refrigerated imbibed storage may be better than either. Seeds tolerate freezing.

Psychotria mariniana (1 yr.)

Viability good after three months under refrigeration, no longer viable after one year. Seeds stored at room temperature and humidity and at low humidity for three months no longer viable.

Psydrax odorata (2 yrs.)

Some seeds remain viable for a year under refrigeration + desiccation; a very few survive two years. Refrigeration would probably work equally well. Seeds stored under room temperature and humidity deteriorate rapidly after six months. (=*Canthium odoratum.*)

Sida fallax (2 yrs.)

Some seeds remain viable for two years under refrigeration + desiccation. Refrigeration would probably work equally well. Seeds tolerate freezing.

Sophora chrysophylla (3+ yrs.)

Akamine (1951) conducted a 42 month storage test at temperatures ranging from 45°F to room temperature and 30-90% relative humidity. Viability remained good under all storage conditions. Akamine suggested that open storage at the lower temperature range would be the preferred condition for longer storage.

Touchardia latifolia (3 mos.)

Viability greatly reduced after three months storage at room temperature and humidity. Good viability under reduced humidity. Seeds tolerate freezing.

***Vaccinium* spp.** (6+ mos.)

Vander Kloet (1993) stored three species of *Vaccinium* in sealed jars at 2°C (34°F) for 6-12 months. He reported good viability for *V. dentatum* and *V. reticulatum*, but greatly reduced viability for *V. calycinum*.

What About Species That Are Not Listed?

It would be convenient if there were criteria to predict the storage behavior of the remaining thousand or so species of Hawaiian seed plants without doing storage tests. Unfortunately, such criteria do not exist. Storage studies which could produce such information will take a long time. In the interim, I offer some guidelines based on research already done here and in other tropical areas (Hong and Ellis 1996):

1. Large seeds which are dropped moist from perennial plants in habitats which rarely dry are likely to be recalcitrant.
2. Small dry seeds are often orthodox.
3. Seeds of Asteraceae, Chenopodiaceae, Lamiaceae, and Solanaceae are orthodox; Brassicaceae, Cucurbitaceae, Fabaceae, Poaceae, and Rosaceae are usually orthodox, with some exceptions; Sapotaceae are recalcitrant or intermediate. Note that plants within the same genus can show different storage behavior.
4. Seeds from achenes, many-seeded berries, many-seeded dehiscent capsules, many dry-seeded pods (but not arillate), many dry-seeded follicles, schizocarps, and urticles are orthodox. Seeds from most siliques and caryopses are orthodox. Note that pods containing 1-5 large seeds or many arillate seeds, berries containing 1-10 seeds, and capsules containing 1-5 seeds may show either storage behavior.
5. Plants growing in environments which are seasonally unsuited for germination usually produce orthodox seeds; some growing in habitats which are moist year-round produce recalcitrant seeds, but others produce orthodox seeds.
6. Dry seeds with hard coats, such as many Malvaceae, are usually orthodox.

If seeds are recalcitrant, storage will be difficult, so the best policy is to plant them immediately instead of trying to store them. Dark imbibed storage may be useful for some species for short periods; for others, it will only stimulate the seeds to germinate.

Experience with native Hawaiian plant seeds suggests that many small dry seeds are orthodox. Such seeds store well under low humidity or refrigeration. When in doubt, this is a good storage method; at worst, it is almost always at least as good as storage at room temperature and humidity.

FOR MORE INFORMATION

The Danish Forest Seed Centre (DANIDA) distributes excellent free literature on seed collection management. Numbers 5 through 9 in the Lecture`Notes "C" series are especially relevant to seed storage. The entire publications list is available for view on the WorldWideWeb at http://home4.inet.tele.dk/dfscdk. Publications are available for order through DANIDA's e-mail address, dfscdk@post4.tele.dk. They are also available by mail through the Danida Forest Seed Centre, Krogeruvej 21, DK-3050 Humlebaek, Denmark. Those seeking deeper technical background and a detailed protocol for testing seed storage behavior should consult Hong and Ellis (1996).

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APPENDIX. Cross Reference of Common and Scientific Names.

ʻakolea	*Boehmeria grandis*
alahe'e	*Psydrax odorata*
ʻalaʻala wai nui	*Peperomia* spp.
au	*Hedyotis acuminata*
haha	*Cyanea angustifolia*
hame	*Antidesma platyphyllum*
ilima	*Sida fallax*
koa	*Acacia koa*
koʻokoʻolau	*Bidens* spp.
kopiko	*Psychotria mariniana*
lama	*Diospyros sandwicensis*
mamane	*Sophora chrysophylla*
manono	*Hedyotis terminalis*
ʻoha wai	*Clermontia kakeana*
ʻohelo	*Vaccinium* spp.
ʻohelo kau la'au	*Vaccinium calycinum*
ʻohiʻa lehua	*Metrosideros polymorpha*
olona	*Touchardia latifolia*
pili	*Heteropogon contortus*
ʻulei	*Osteomeles anthyllidifolia*

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The annual Hawaii Conservation Conference, sponsored by the Secretariat for Conservation Biology, is the largest gathering of people involved in the protection and management of Hawaii's native species and ecosystems. It is attended by 350-400 people. The purpose of the conference is to facilitate interaction among natural resource managers and the scientific community. It is an opportunity to discuss and obtain up-to-date information on a variety of conservation activities in Hawaii. For more information, contact the Secretariat for Conservation Biology's website at: http://www2.hawaii.edu/scb.

Propagation Techniques for Native Hawaiian Plants

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Propagating native Hawaiian plants is not well understood or documented. The National Tropical Botanical Garden (NTBG) has experimented with seed preparation, germination techniques, various media, and other propagating methods since 1988 with native Hawaiian plants. Most of these species have never been grown in cultivation before. Many are rare and endangered species and come from a diversity of habitat types. Below are some general guidelines that have proven successful at NTBG's nursery.

Seed Collecting

For optimum germination, collect seeds that are mature or ripe. If seeds are gathered when the embryo is insufficiently developed, the seed is apt to be thin, light in weight, shriveled, poor in quality and short-lived, all of these impairing germination.

Seed Cleaning

Dry Seeds (i.e., *Achyranthes, Bidens, Charpentiera, Dodonaea, Dubautia, Heteropogon, Jacquemontia, Mariscus, Panicum, Portulaca, Schiedea, Sida, Wilkesia*)

1. Leave seed material out at room temperature to air dry or in a paper bag.
2. Set a strainer over a bowl (Choose a strainer according to seed size. All sizes of strainers are useful)
3. Empty seed material into the strainer and carefully rub it so that the seeds fall enough the strainer and the debris is left.
4. Discard the debris. (Match strainer holes to seed size.)

Fleshy or Pulpy Seeds (i.e., *Alyxia, Bobea, Diospyros, Ilex, Neraudia, Osteomeles, Pipturus,Psydrax, Reynoldsia, Santalum, Scaevola, Streblus, Wikstroemia*).

1. Ripen seeds in a plastic bag. (Seeds are easier to clean when the pulp is softened.).
2. Once ripened, remove the flesh to prevent spoilage:

   A. One way is to use a colander or strainer placed under running water. Rub seeds to dislodge pulp, (this works best with larger seeds).

   B. Another way is to put the seeds in a large bowl of water, then massage the seeds by hand to separate the seeds from the pulp. The heavy, good seeds will sink to the bottom. The lighter pulp and empty seeds will float to the top and can be poured off.

3. Wash the seeds thoroughly.
4. Dry them on a paper towel.
5. Now they are ready for storing or planting. (*Note*: Not all seeds sink, some like the *Cordia, Scaevola, Santalum*, and others, float which is the way they disperse).

Manual Cleaning (i.e., *Acacia, Alphitonia, Caesalpinia, Canavalia, Colubrina, Erythrina, Gossypium, Hibiscus, Kokia, Pittosporum, Pritchardia, Senna, Sesbania, Sophora*).

Most seeds that occur in pods or capsules can be manually removed by ripping the pods apart and removing the seeds. A hammer, nail-clippers, and other implements come in handy. Be careful to avoid damaging the embryo.

Cleaning *Pritchardia* Seeds

To ripen green seeds, place them in a zip lock plastic bag (2-4 weeks) until mesocarp is soft and dark (not rotten). Then use a knife to remove the mesocarp. Immature *Pritchardia* seeds are much more difficult to clean than ripe seeds. Soaking the seed in tap water for 24 hours will help soften the mesocarp and make it easier to clean.

Propagation of Seeds

For successful germination, seeds must be viable with the embryo alive and capable of germination. They must also have available water, the proper temperature, a supply of oxygen, and sometimes light. At best, seeds should be started fresh, not dried or from storage. If the seed is dormant, dormancy can be broken by various treatments, as described.

PRE-TREATMENTS

Water Soaking (i.e., *Alyxia, Capparis, Colubrina, Dodonaea, Hibiscus, Jacquemontia, Nestegis, Osteomeles, Pntchardia, Scaevola, Sesbania, Senna, Sida, Vitex, Wikstroemia*)

Seeds are sometimes soaked in water before planting to hasten germination and overcome dormancy. Water is absorbed by the dry seed and the moisture content increases rapidly at first, then it levels off. The seed swells and the seed coat may break open. Hot or cold water can be used. Hand-hot water (120-135°F) is recommended for harder seed coats . At the same time, non-viable seeds can be discarded after soaking 12 hours or so. They tend to float while the heavier, viable seeds sink. Note: Not all seeds sink, some are meant to float in water like *Scaevola* and *Gossypium.*

Soaking time can vary from a couple of minutes to 72 hours or more, depending on the seed coat. Use about twice as much water as seeds. The thicker the coat, the longer the soaking time. Change water daily. Be careful not to soak to long, because excess water can get trapped between cotyledons and suffocate the embryo.

Scarification

Physical Scarification (i.e., *Acacia, Caesalpinia, Canavalia, Erythrina, Kokia, Sapindus, Senna, Sesbania, Strongylodon*)

Scarifying hard seed coats for uniform germination by rubbing with sandpaper or a file, nicking with nail-clippers, or cracking with a hammer are simple methods that are useful for scarifying small amounts of large seeds.

NO PRE-TREATMENTS

(i.e., *Brighamia, Cyanea, Delissea, Xylosma, Cyrtandra, Myrsine, Labordia, and Viola*).

Very small seeds from wet habitats generally do not require pre-treatments. They need to have the pulp completely removed from the seeds or they will succumb to fungi and molds, and may rot. Using fungicides can help to accomplish this.

Some of these plants produce extremely tiny seeds within a fleshy fruit (i.e., Campanulaceae family). To avoid loss of seeds or viability, it is helpful to use fungicides in preparing the seeds before planting. A fungicide can be made into a solution and mixed with the ripening fruits in a plastic bag. The more the fruit ripens the better.

Once the seed material is ready (1 to 3 days), squeeze the bag gently to break up the pulp, pour into a glass jar and let seeds settle to the bottom. Remove as much of the floating pulp as possible.

Prepare a well-drained medium of 2 part peat moss or 1 part potting mix to 1/2 part perlite. Pour this "slurry" substance onto your planting media and place under protected conditions such as a mist bench or mist box.

Plants from wet habitats may need to be started in covered containers, creating a terrarium-like effect. Another way to accomplish this is to place the pot in a plastic bag and place in a shady place. It helps to provide the damp growing environment that these plants need to germinate. The fungicide will reduce the amount of seed rotting that can occur when so much pulpy material is planted with the seeds.

SEED STORAGE

Seeds can be stored for varying lengths of time after collecting. Viability at the end of any storage period is the result of the initial viability at harvest. The most important condition is the low moisture content of the seed during storage. Seeds can be dried using silica gel or other desiccants. Store the dried seeds in airtight containers in a cool dry area. Some seeds, such *as Erythrina, Canavalia, Caesalpinia* and *Koa*, can be stored in a refrigerator. Seeds shcuild be cleaned, removed from their pods, and have all pulp removed. Do not soak or scarify seeds that are to be stored. Not all seeds can be stored, as they will loose their viability, such as plants in the Araliaceae family (*Munroidendron, Tetraplasandra*) *Pritchardia* palms, and others such as *Alyxia* and most of the plants in the Campanulaceae Family.

MEDIA

Seed Media (soil-less mix). The absence of soil reduces the risk of damping-off and other soil-borne diseases. It also is free of any weed seeds or pesticides. The germination medium must retain moisture, yet provide good drainage and aeration. Different combinations of potting mix, perlite, and cinder are used.

- 2 or 3 parts perlite to 1 part potting mix (Sunshine Mix #4)
- 1 or 2 parts fine cinders to 1 part potting mix (used for *Metrosideros* spp.)

The mix should have excellent drainage to inhibit damping-off and reduce crusting. Surface sow small seeds by dusting them on the media surface. Medium-sized seeds are covered lightly to about the diameter of the seed. Larger seeds may be planted at the depth of two or three times their diameter. Place seed flats in a covered, 50%

shaded area and water regularly every other day or when dry.

Cyanea, Delissea, Xylosma, Cyrtandra, Myrsine, Labordia, and *Viola* seeds from wet forest areas and very small seeds should be surface sowed on sphagnum moss or 3 perlite and 1 potting mix put under or in a closed mist system (every hour for 15 seconds from 6am to 6pm). This also works well for *Pritchardia*'s from wet areas (*P. viscosa, P. waialealensis*).

Proper moisture conditions during germination are essential. The medium should not dry out or remain so wet that damping-off becomes problem. Germination can vary from about 1 week to 2 to 3 years (depending on the species). Keep the seeds under cover, in a shaded area and out of the rain and wind.

Transplant Media. After 2 to 4 true leaves have appeared, the seedlings should be transplanted. Remove the seedlings from the medium with your finger, a pencil, or your hand by moving in under the medium and seedling. Handle the seedlings by their leaves, not the stem which is easily damaged by pressure. Be very careful to avoid root damage. Choose a pot according to the size of the root system of the plant. Don't "over-pot seedlings," in other words, don't put a small seedling in a pot many sizes larger than its root system. Fill the pot a third of the way, add the seedling, then add the remaining medium, cover roots, and tap down gently to stabilize the plant. Water thoroughly. It is critical that the media drains freely. To test this make sure that water does not sit on top of the media when watered. Keep in a covered, shaded area for 2 to 3 weeks. To prevent damping-off, add a thin layer of perlite to the surface or keep the media somewhat dry on top. A recommended transplant medium is:

- 4 parts potting mix
- 2 part compost
- 4 parts perlite (#2 or #3), or medium size cinder.

Cuttings & Media (i.e., *Achyranthes, Bidens, Broussonetia*, ferns, *Hibiscus, Lipochaeta, Nototrichium, Phyllostegia, Portulaca, Schiedea, Vitex*)

Media for cuttings is made up of different combinations of perlite, vermiculite, potting mix or oasis cubes, such as:

- 2 to 3 parts perlite to 1 part vermiculite or
- 2 to 3 parts perlite to 1 part potting mix
- Oasis or rooting cubes

Note: Do not add vermiculite to the potting mix because it will hold too much water.

The cutting media has three functions: 1) to hold or support the cutting in place during the rooting period; 2) to provide moisture for the cutting; and 3) to permit aeration to the base of the cutting. Cuttings are taken from the vegetative portions of the plant such as stems, modified stems (tubers, rhizomes, etc.), leaves, or roots. Cuttings should be taken in the morning from healthy, vigorous growing plants. This means that they should have an ample supply of stored foods to nourish the developing roots and leaves until the new plant becomes self-sustaining, it will help to remove all lower foliage and bug infested leaves. Do not let the cutting material dry out at any time. Zip-lock plastic bags can help keep the moisture in when transporting the cuttings to the nursery.

Reduce the foliage on the cuttings if a mist bed is not available. Rooting hormones (#1-3, 8) are used on green, semi-hardwood or hardwood cuttings. Herbaceous material, such as *Phyllostegia* and *Cyanea,* need no hormone. A hormone with a fungicide in it is helpful. Cuttings will root anywhere from 1 month to 6 months, look for new leaf and root growth. Pot up as you would a seedling, avoiding root damage. Keep the re-potted cuttings in a covered, shaded area for 2 to 3 weeks. Use a well-drained medium such as:

- 2-3 parts potting mix
- 2 parts perlite
- 1 part compost (or 1 part fine cinder)

Fern Spores. Place mature fronds with sori in a paper bag for 2 to 3 weeks. Sterilize a clear plastic shoe box and oasis cubes (or sphagnum moss) with hot water. Let the box and media cool, then surface sow spores on top of the growing media in the box and cover. Keep moist, spores will germinate in 1 to 6 months depending upon the species. Transplant into 3 parts potting mix to 2 parts perlite, and put under a dosed mist system for 1 to 3 months gradually moving out of the mist to a shaded area.

Fertilizer. Use a balanced fertilizer such as triple 8. However, since native plants are sensitive to fertilizers, half of the recommended dosage is more successful. Micro Nutrients are also helpful. Add the fertilizer when mixing the media; do not apply to the surface after potting. Foliar feed your plants with a liquid fertilizer once a month. Be careful when fertilizing your native plants because more is not always better. *When in doubt, use less!*

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